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Parameter estimation of stellar-mass binaries with eccentric orbits in LISA

Aaron Rogan

Sukanta Bose and Achamveedu Gopakumar

Relativity Group at Washington State University and

Theoretisch Physickalisches Institut at Friedrich Schiller Universität

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What Is To Come!!!

- How do we track eccentricity
- Relevance of eccentricity
  - Should eccentricity be considered
  - What can be missed without it
  - What can it tell us
- Goals of the research
  - Why do error estimation
- Parameter Estimation
  - Without eccentricity
  - With eccentricity
- Summary/Conclusion
  - Insights obtained
  - Scope for future work

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The Waveforms Considered

- **Fully self consistent 1PN waveforms** (Tessmer 2006)
  - Semi-analytic waveforms
  - Obtain accurate orbital dynamics
  - Stellar mass binary systems
  - Eccentricity ranges up to 0.6
  - Non-chirping sources (no TDI or Doppler phase either)
  - Orbital periods up to 1 day
  - Computationally cheap
- **Opposed to Newtonian quadruple waveforms** (Moreno 1995)
  - Periastron advance done by hand
  - Bessel function expansion
  - Computationally expensive
  - Long integration times result in signal dropping out-of-phase with the templates

Do We Really Need To Consider Eccentricity?

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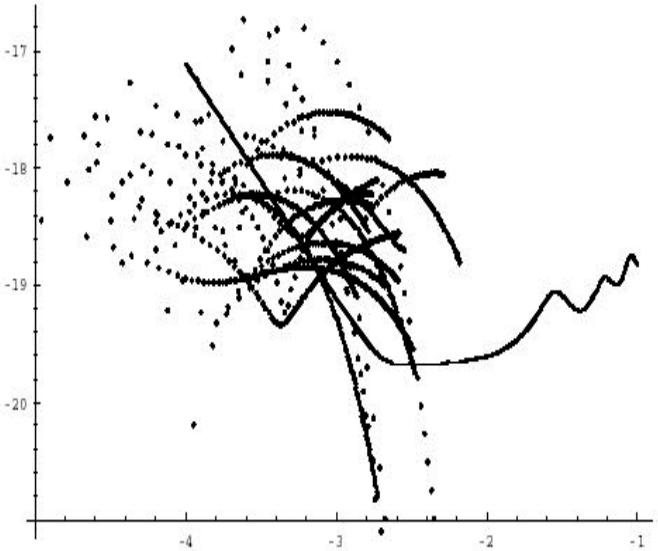
- Population rates are ambiguous and changing for most sources, eccentric or not (i.e. BNS, BBH, BWD, etc)
  - Example: 0.1-7 per year detectable eccentric BNS (Seto 2001, Gusev 2002)
- Increase chances of a signal detection
  - Tracking eccentric binaries with non eccentric templates
    - Can lose up to 10% in SNR with just 0.1 eccentricity (Martel 1999)
  - Dig out sources in the CWDB's confusion noise
    - Eccentric sources emit frequencies at multiple harmonics of fundamental mode
      - Fundamental mode within confusion noise
      - Higher harmonics outside of the confusion band (Seto 2001, Benacquista 2001)



(Benacquista 2001)

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What Can We Learn From Eccentric Sources?

- Test General Relativity predictions
  - Theoretical predictions of the periastron advance (Seto 2001)
  - Measure the mass of the graviton (Jones 2005)
- Obtain larger picture of binary system
  - Without eccentricity: location, orientation, frequency, chirp, and distance
  - With eccentricity: eccentricity and possibly individual masses at 1PN order (without chirping)
- Get information about globular cluster dynamics and populations (Benacquista 2001)

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What Regions of Parameter Space Are Most Important or Least Important?

- To get a handle on the answer, four cases were examined in great detail
  - Bare signal with no Doppler shifting or chirping
    - Low frequency and low mass sources
      - f<1mHz
      - BBH or less mass range
  - Doppler signal without any chirping
    - Low mass sources
      - White dwarf mass range
  - Chirping signals with no Doppler shifting
    - Low frequency high mass sources
      - f<1mHz
      - BBH or greater mass range
  - Full signal with both Doppler shifting and chirping
    - Valid at any frequency and mass range
- What complications does the eccentricity introduce?

Lets Start In Frequency Space

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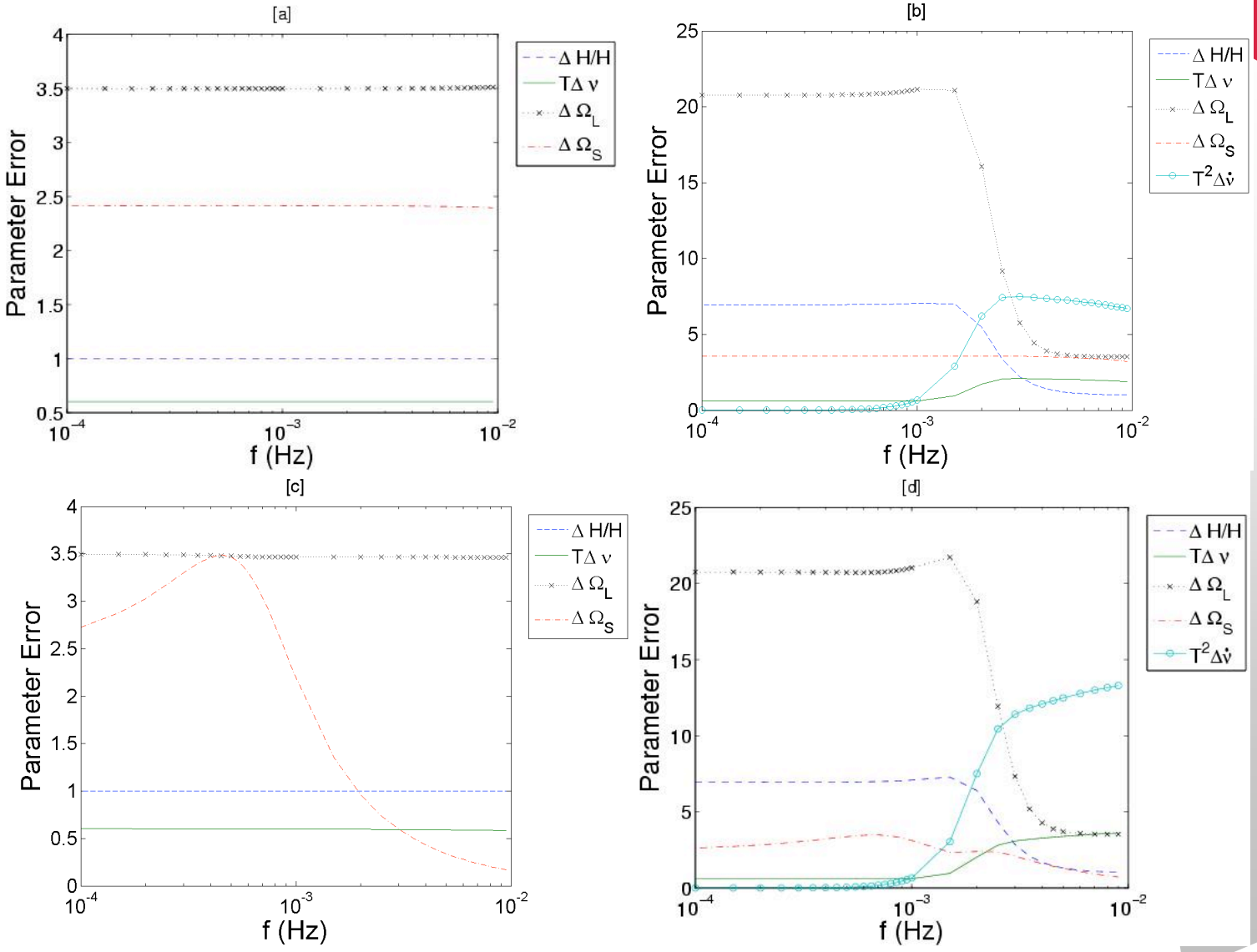
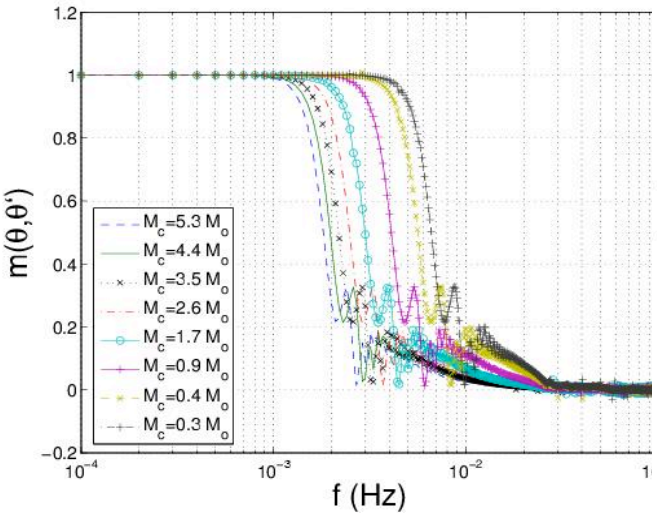
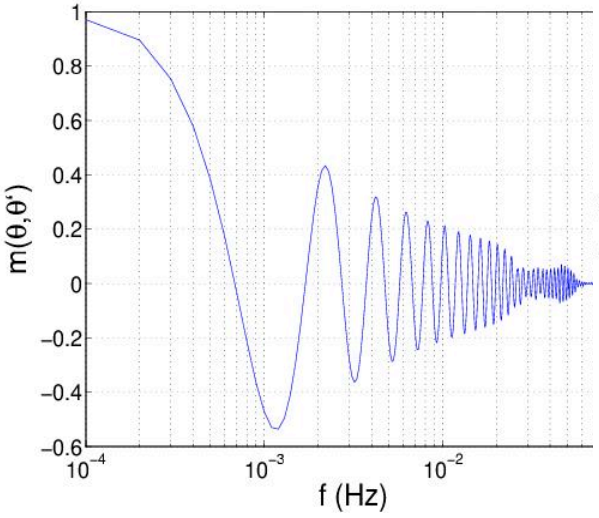
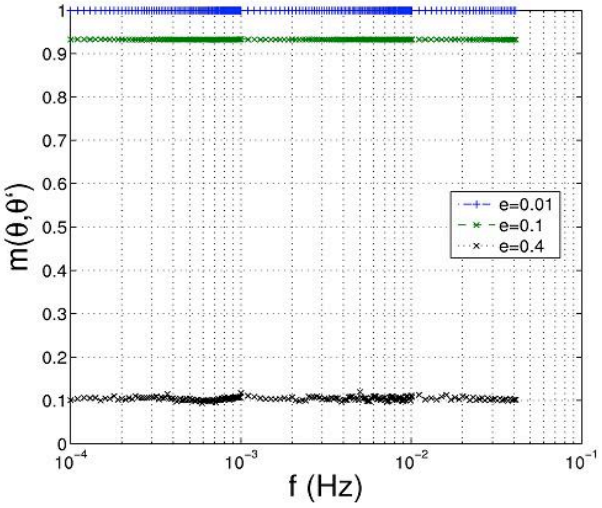


Something Else Interesting In Frequency Space







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Complications From Eccentricity In The Time Domain!!

- No longer simple sinusoids
  - Superposition of multiple sinusoids

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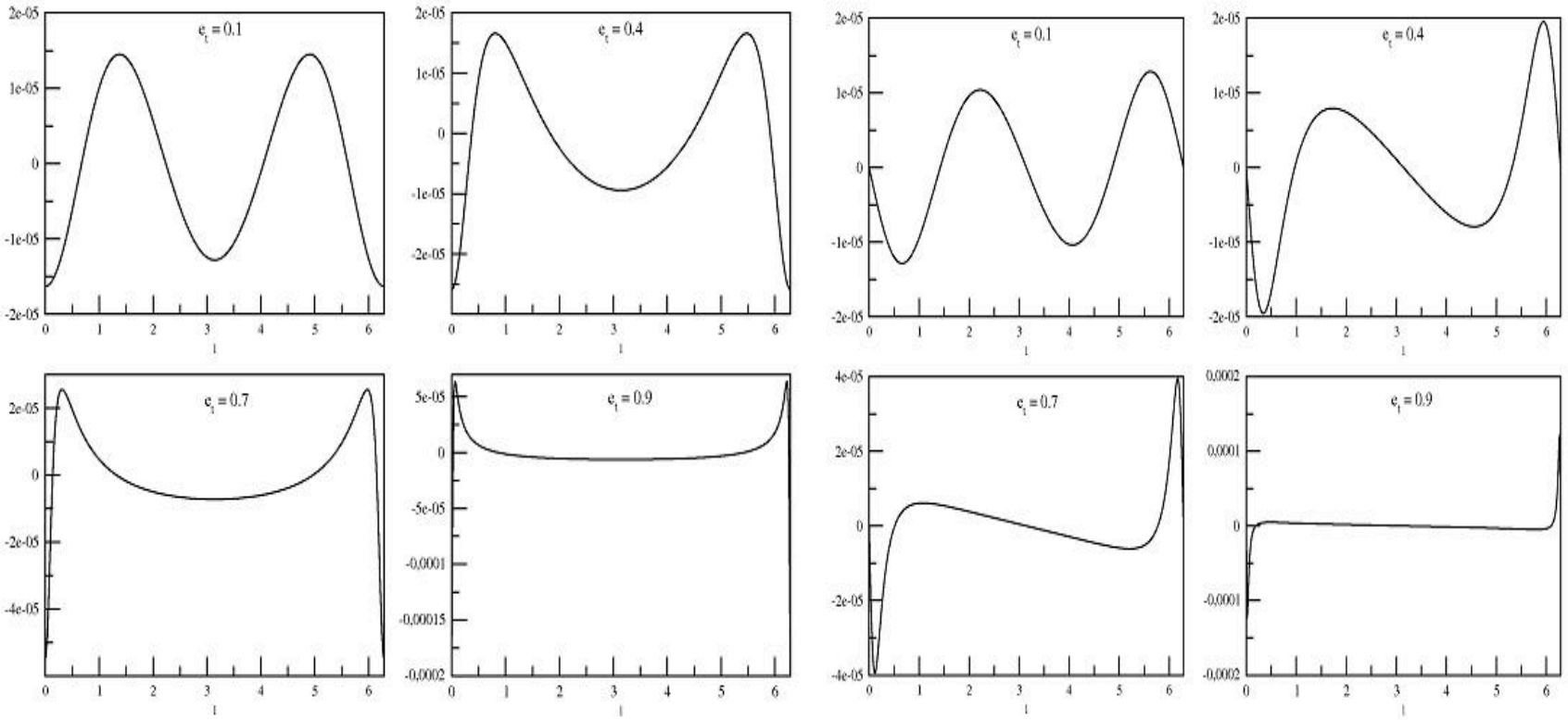

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Complications From Eccentricity In Frequency Space!!

- No longer just a single emission frequency
  - Multiple harmonics are present

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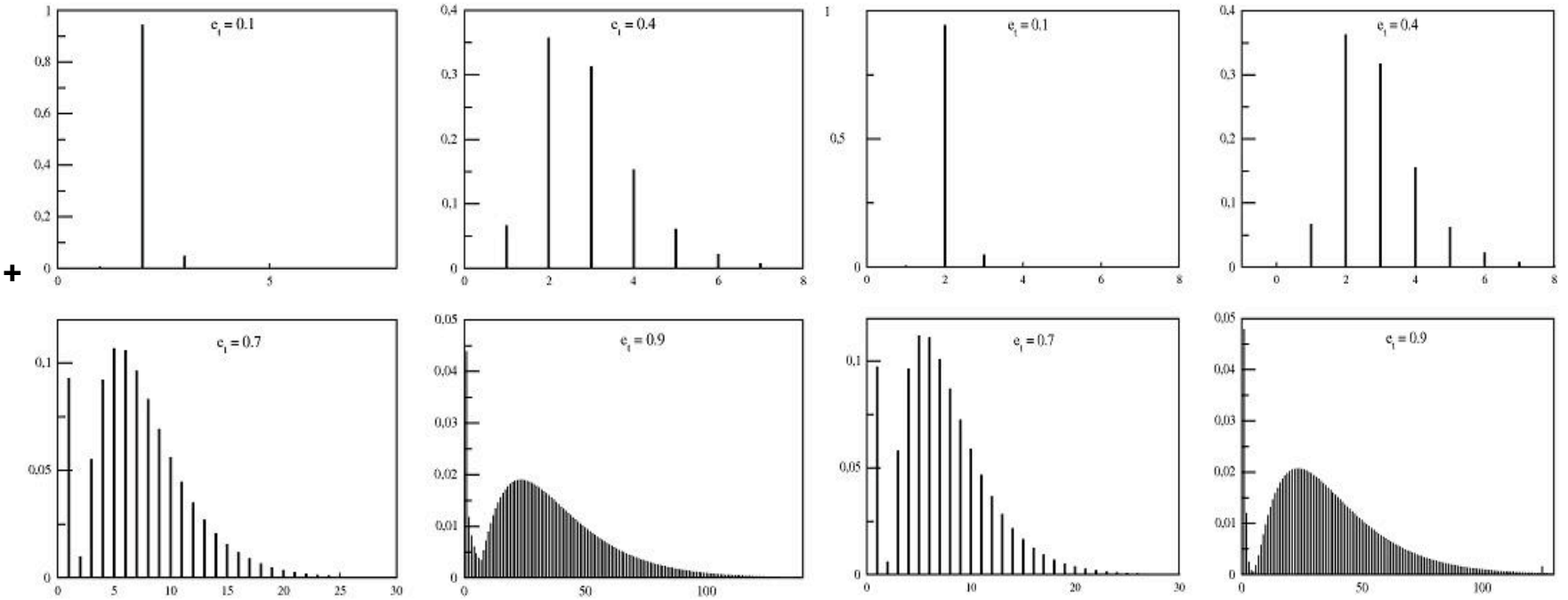

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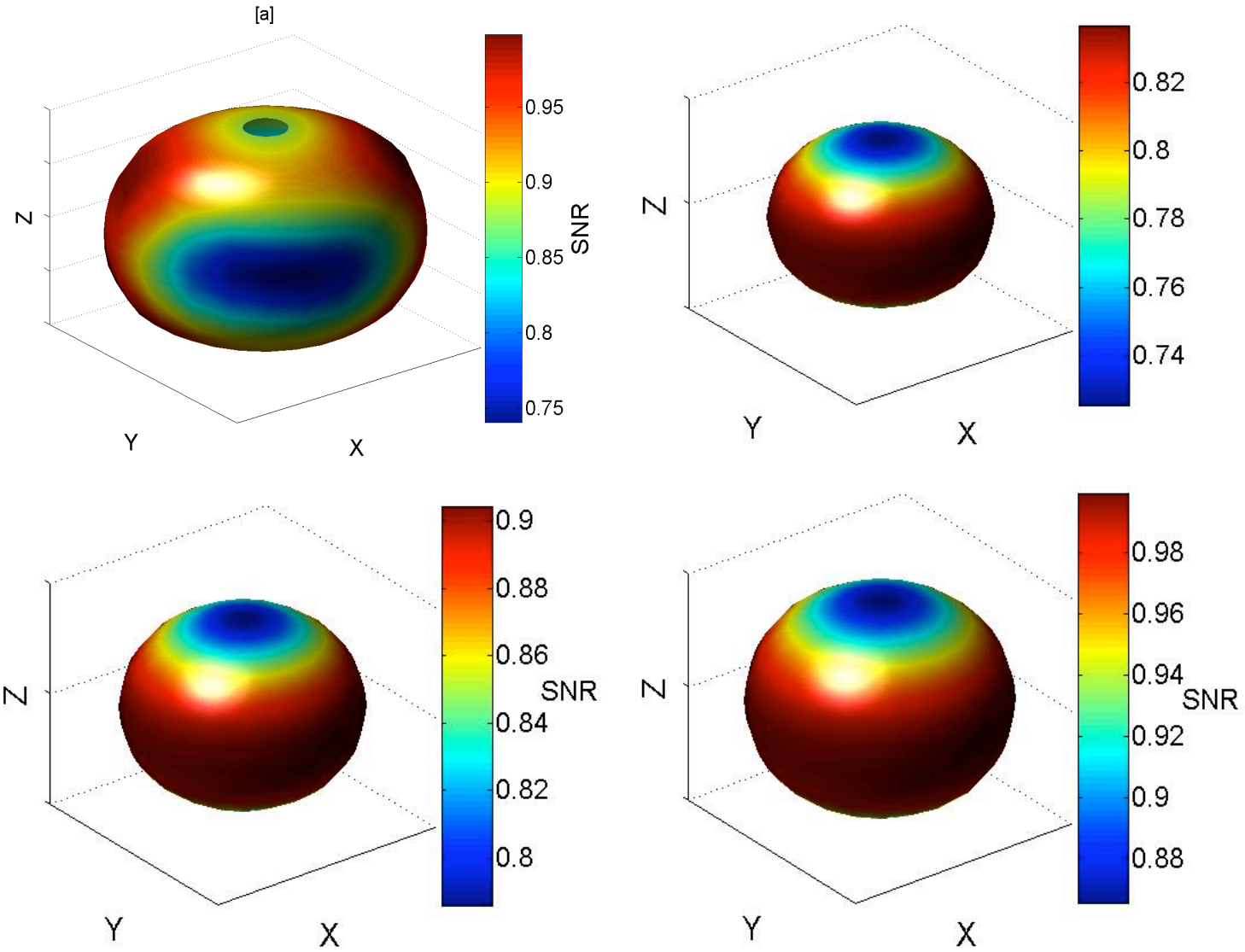
Lets Look at the Signal



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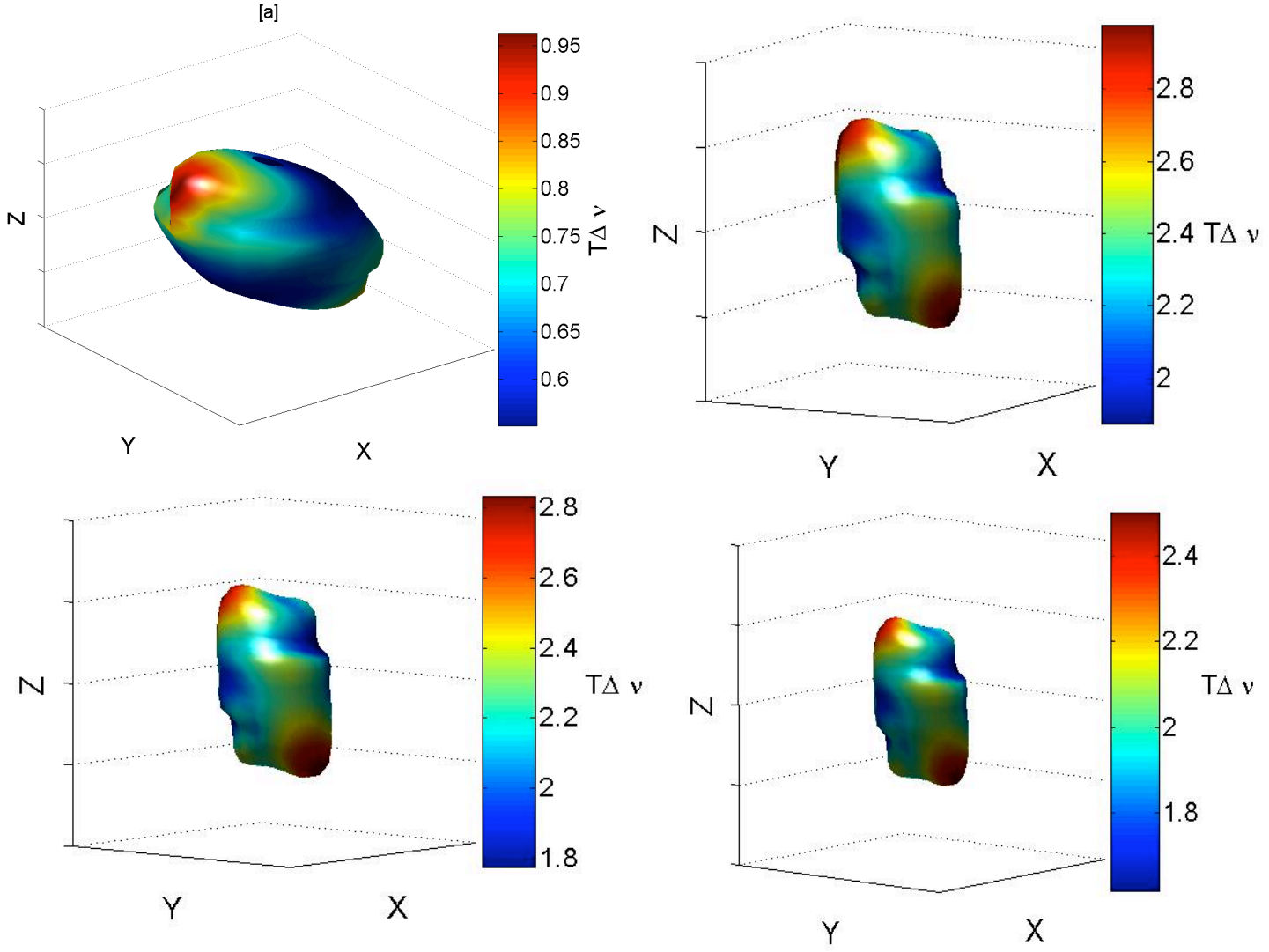
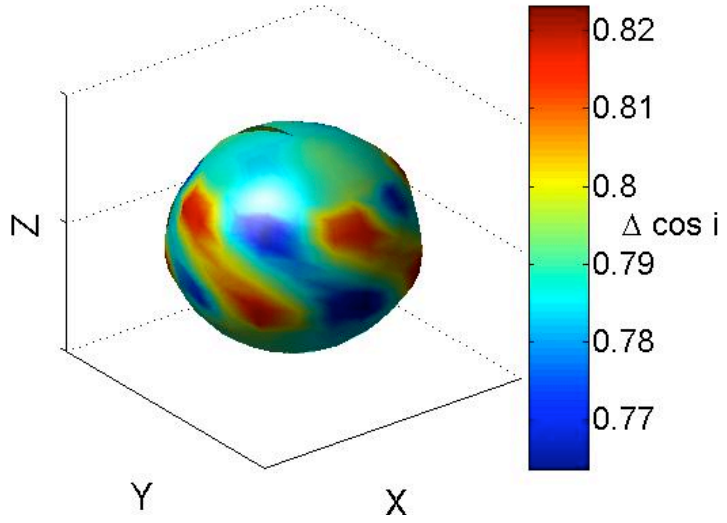
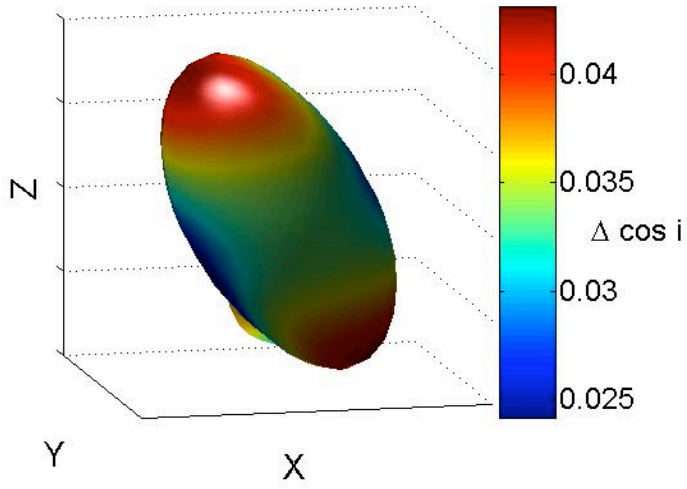
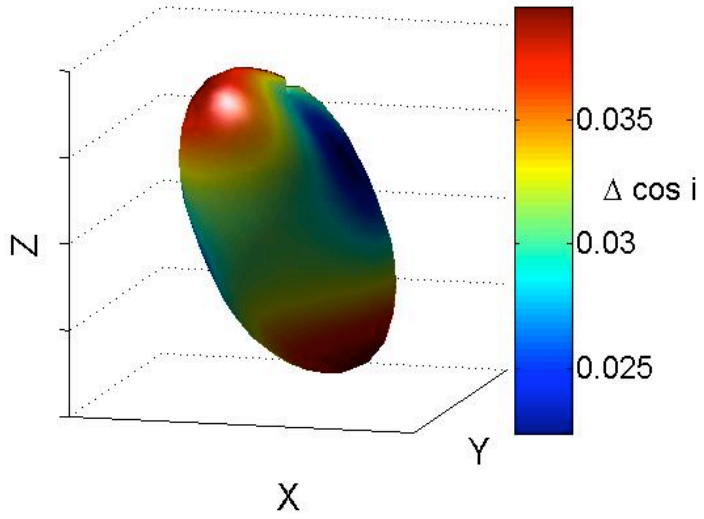
What Do Errors Look Like?

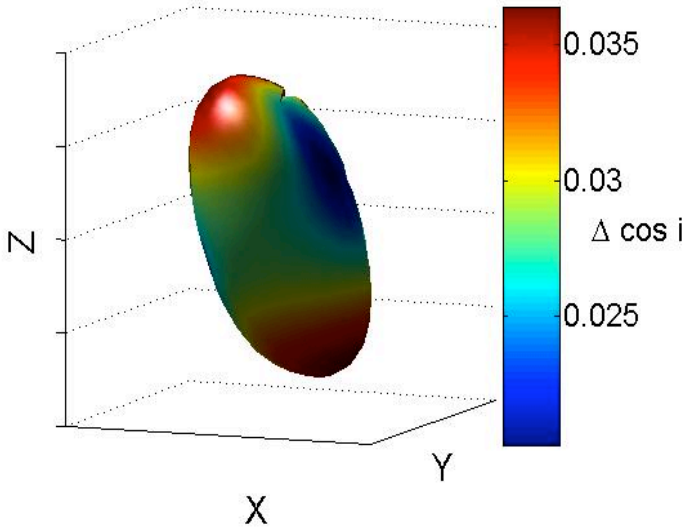


Parameter Improvements









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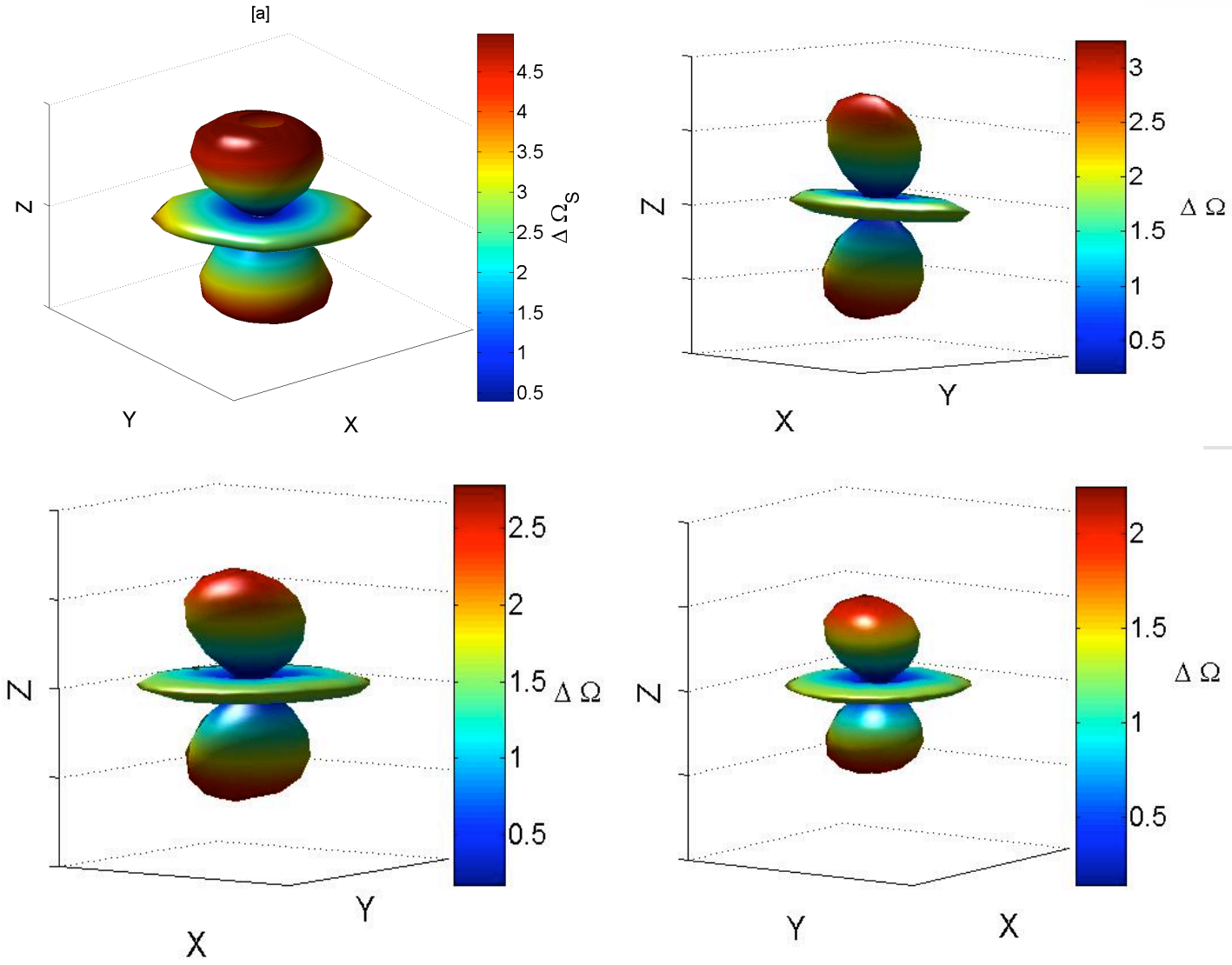
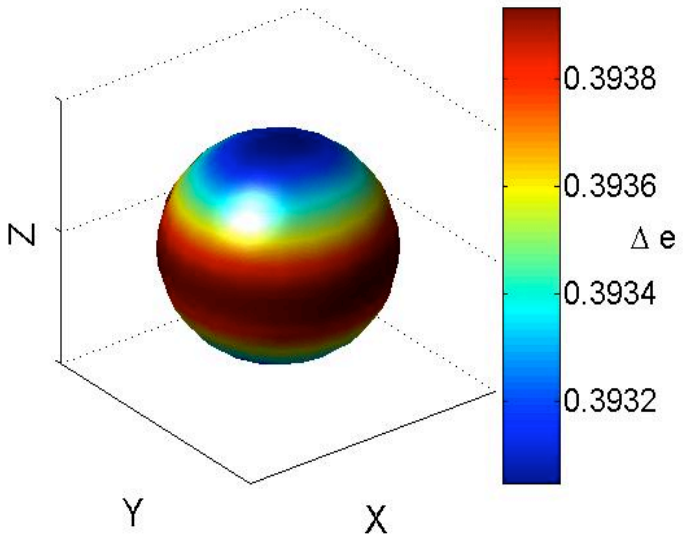
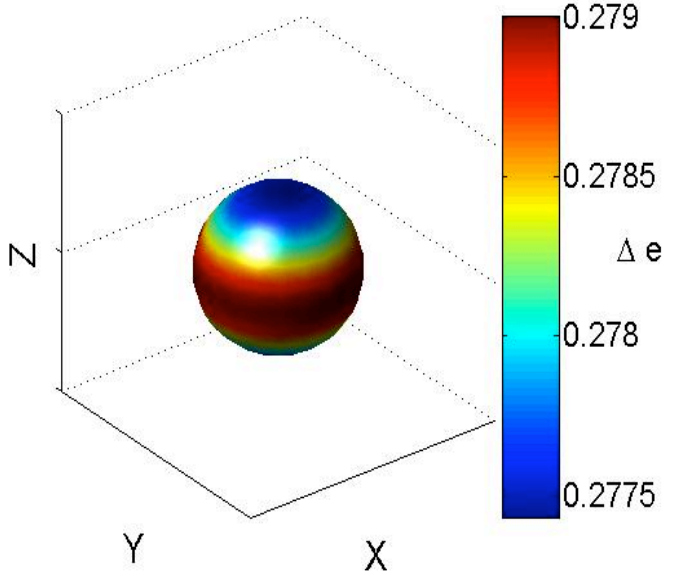
Parameter Improvements

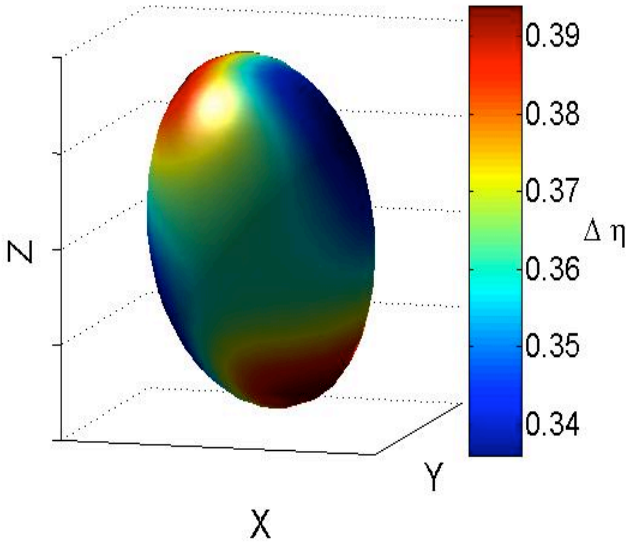


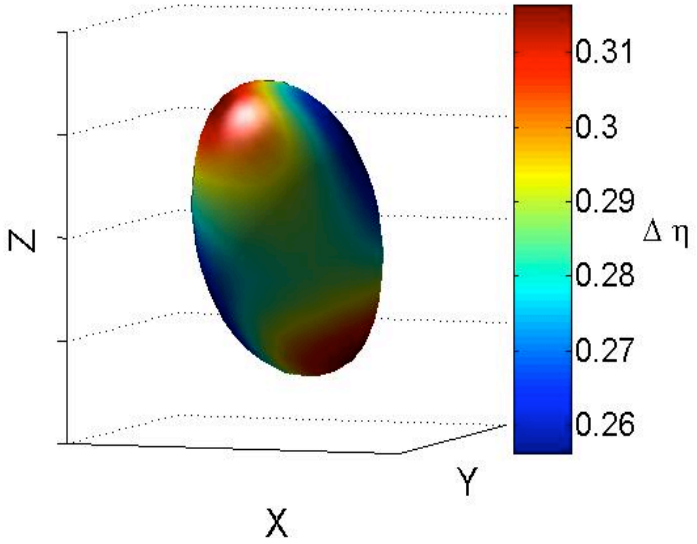
New Parameters

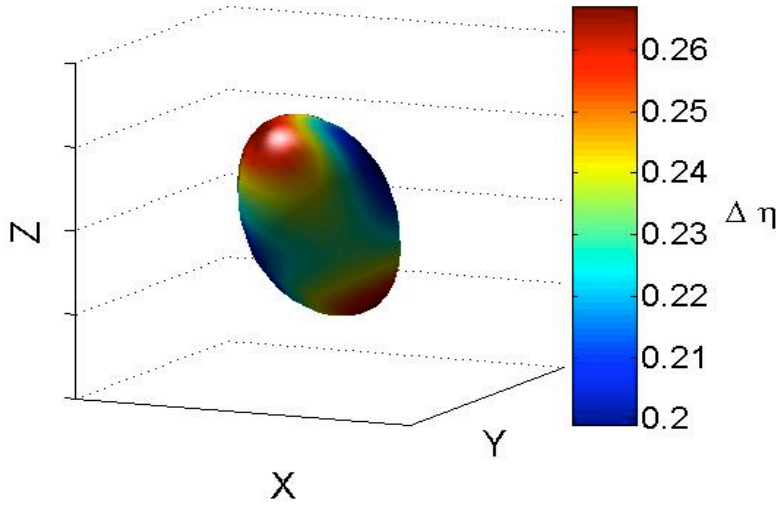




Mass Errors







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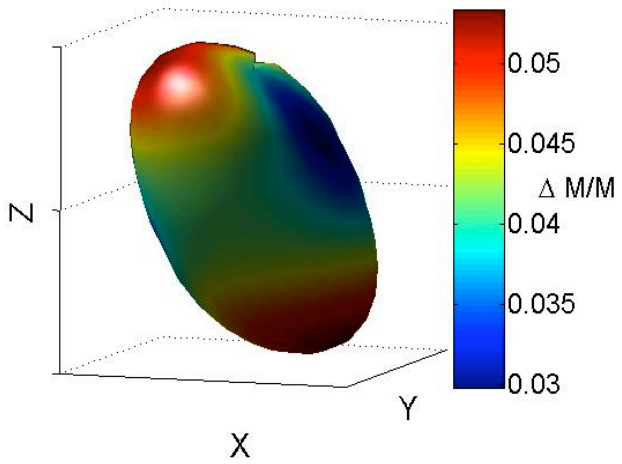
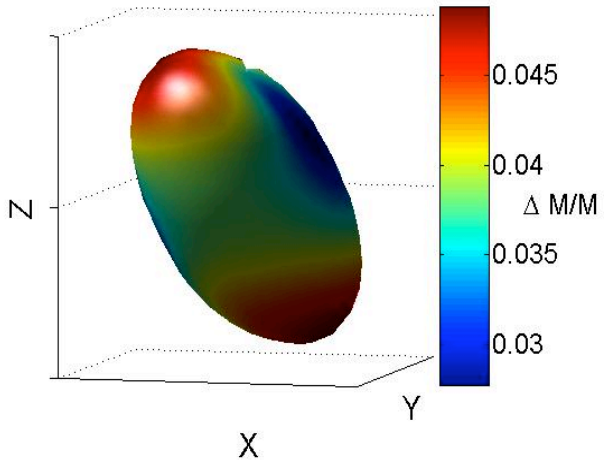
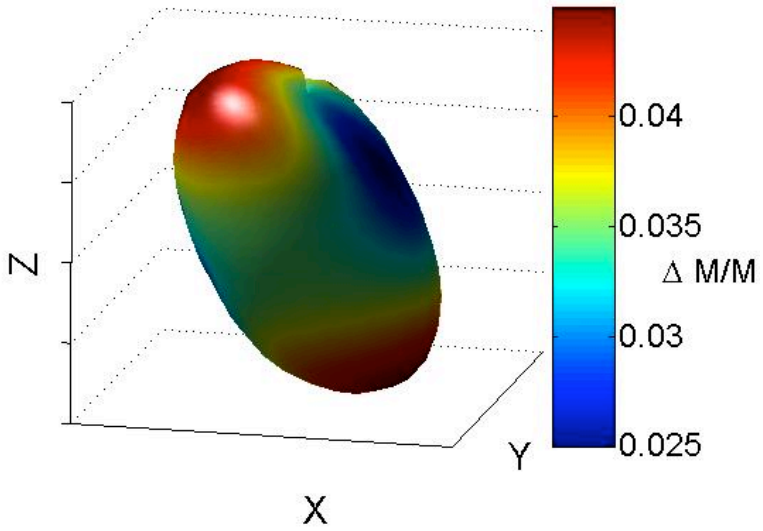
Total Mass







Summary

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- Eccentricity improves some parameter errors
  - Inclination error 0.02-0.04 radians (order of magnitude better)
  - Source location 0.25-3 steradians (roughly 33% improvement)
- Eccentricity degrades parameter errors
  - Frequency 1.6-3 cycles (roughly 3x decrease)
- New parameter measurements
  - Both total mass and eta error are in ranges obtained for SMBH calculations shown earlier this week
  - Eccentricity errors agree with those presented in literature (roughly around an error of 15%)
- What is next
  - Incorporate Doppler phase
  - Increase mass range, incorporate spin and chirping while adding higher order PN corrections to waveforms
  - Online Live LISA